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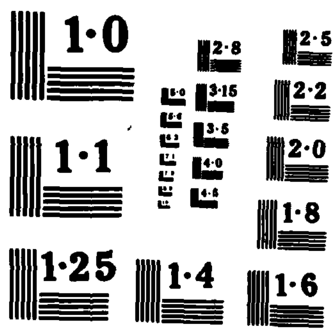
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16. Abstract

FAA-funded Doppler weather radar activities during the period 1 July to 30 September 1984 are reported.

The test-bed Doppler weather radar was moved to the Olive Branch, Mississippi test site in early July. System integration and testing at Olive Branch commenced in mid-July. In late August, two lightning strikes damaged the mount electronics, computers, and signal-processing electronics. Most of September was spent in assessing and repairing the damage as well as installing an improved lightning protection system.

The other principal weather measurement sensors (Lincoln mesonet, Memphis airport LLWSAS, and University of North Dakota C-band weather radar) obtained useful data in the July to September time period. These data and data from the National Center for Atmospheric Research JAWS program and the National Severe Storms Laboratory are being analyzed to determine wind-shear detection algorithms. Clutter measurements were carried out at the Dallas-Ft. Worth airport.

Work continued on development of Doppler-radar-derived weather products for the Central Weather Processor. This work focused on optimization for algorithms for producing layered reflectivity and turbulence fields, and products for depicting the three-dimensional structure of storm fields.

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WEATHER RADAR STUDIES

I. INTRODUCTION

The principal areas of emphasis for the weather radar program over the past quarter have been:

(a) Development of a transportable Doppler weather radar test-bed to be utilized in a series of experimental programs during 1984-86.

(b) Reduction of data from the coordinated Doppler weather radar - aircraft - mesonet experiments in the Boston, Massachusetts area during the summer of 1983.

(c) Planning for the first set of transportable test-bed experiments in the Memphis, Tennessee area.

(d) Evaluation of the utility of strawman NEXRAD products for various ATC users in connection with the NEXRAD Interim Operational Test Facility (IOTF) Boston Area NEXRAD Demonstration (BAND).

(e) Development of detailed specifications for certain Central Weather Processor (CWP) products to be generated by the NEXRAD system.

Progress in each of these areas is described in the sections which follow.

II. TEST-BED DEVELOPMENT

The principal objectives for the transportable test-bed have been to develop a NEXRAD-like Doppler radar which can be used for:

(a) Resolving the principal uncertainties in algorithms for detection and display of enroute and terminal hazardous weather regions.

(b) Obtaining feedback from operationally oriented users on the utility of straw-man end products for improving safety and efficiency of airspace utilization.

(c) Investigating Doppler weather radar – CWP interface issues.

(d) Providing a data base for FAA specification of NEXRAD, terminal weather radar, and NEXRAD/CWP interfaces.

During the 1984-85 experiments, the transportable test-bed radar will be used in the following modes:

(a) As a terminal Doppler weather radar to detect low-altitude wind shear (LAWS) and other hazards both:

   (1) "On-airport" using 360° PPI scans with principal focus on glide slope headwind/tailwind shear, and

   (2) "Off-airport" using sector PPI scans with occasional RHI scans to focus on microburst/downburst detection in midair stage.

(b) As a NEXRAD "network" sensor with a 5-min. volume scan and principal focus on products of particular interest to the FAA such as turbulence, layered reflectivity, and LAWS.

(c) For "scientific" data acquisition (as in the JAWS and NIMROD projects) characterized by scientist-controlled scan patterns based on real-time three-moment displays.

Figure II-1 shows a block diagram of the test-bed.

The test-bed radar installation at Lincoln was turned off on 10 June to commence packing operations. The system arrived in Olive Branch 2 July. Figure II-2 is a photograph of the test-bed system at the Olive Branch test site in early July. System integration and testing proceeded through the remainder of July and August.

In late August, two lightning strikes damaged the mount electronics, computers, and signal-processing electronics. The first strike on the radome lightning rod arced over to a mount power line when the grounding rod proved incapable of discharging the strike. This arcing caused damage to the radome backup diesel generator as well as to the mount electrical and electronics systems.

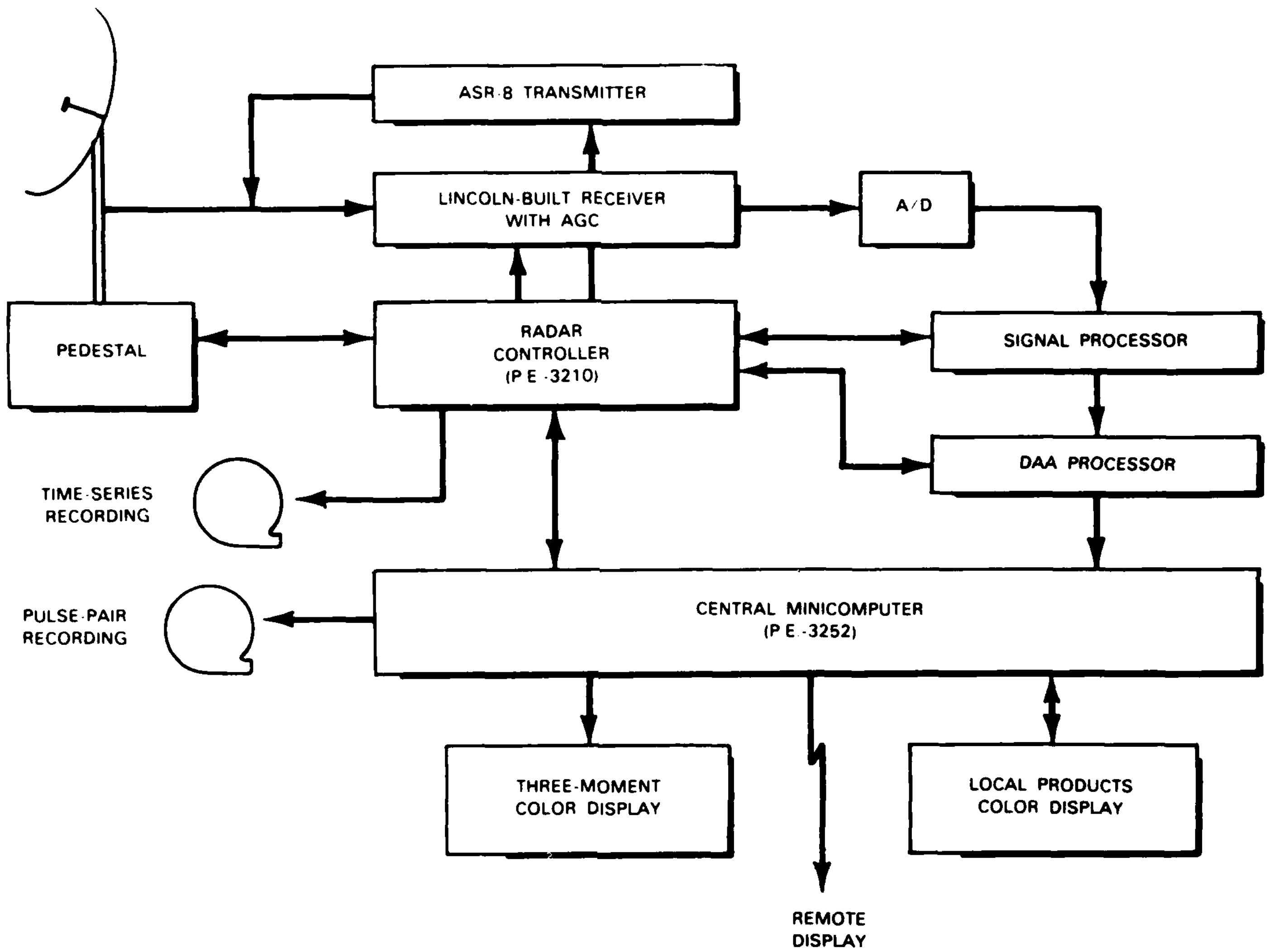

Figure II-1. Test-bed block diagram.

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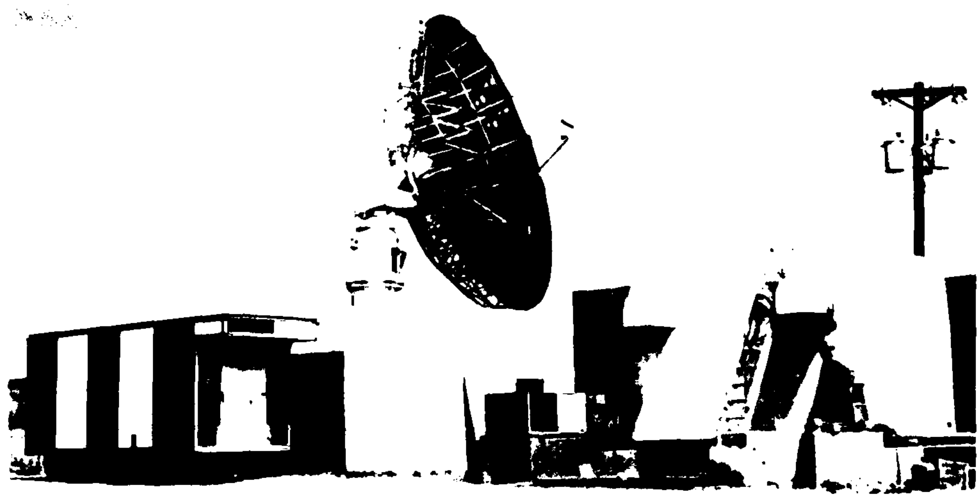

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Figure II-2. Test-bed Doppler weather system at Olive Branch, Mississippi.

The second strike on the power company pole weakened a transformer which then blew up approximately 1/2 hour later. The surge from the transformer failure caused damage to virtually all of the signal processing interfaces as well as to computer terminals, etc.

Thus, we spent most of September in assessing and repairing the damage as described in the following sections. A series of discussions were held with the FAA lightning protection experts as well as with the NCAR engineers (especially C. Frush) who have implemented a lightning protection system on the NCAR CP-2 radar. We are in the process of implementing the principal features suggested by these authorities and the FAA lightning protection manual:

(a) Installation of an underground counterpoise around the principal site buildings (Figure II-3).

(b) Use of a local diesel generator when lightning may occur in the power company region.

(c) Shielding and surge suppression for the power lines and for the signal lines between various site buildings.

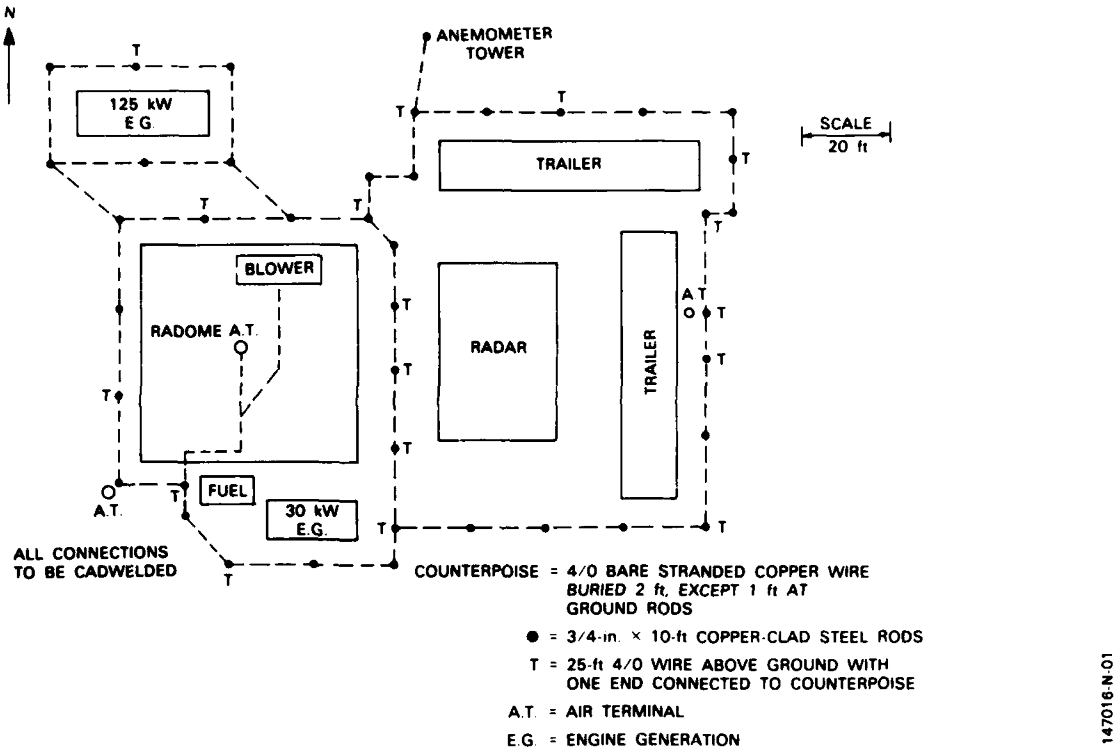

Figure II-3. Grounding counterpoise.

We anticipate that the substantial underground work will not be finished until late November 1984 due to weather and procurement delays. Thus, although system integration and clutter suppression tests can proceed, operation in the presence of nearby weather will be delayed until December.

A. RADOME

The radome installation was scheduled for 21 July. However, a BirdAir representative expressed concern as to the hold-down strength of the retaining ring. We decided to delay installation until early August so that the additional screws could be placed through the retaining ring down into the concrete structure upon which the radome sits. These changes were accomplished in early August and the radome was installed and inflated. It has operated satisfactorily except for the brief deflation that occurred with the lightning strike. Fortunately, the radome was not damaged in the deflation.

B. ANTENNA

The antenna arrived in Olive Branch and was easily reassembled. Measurements indicate that it is essentially unchanged mechanically from its condition before pattern testing. Preliminary

electric measurements indicate a VSWR of 1.38, whereas our objective was a VSWR of 1.30. We plan to improve the VSWR by reducing the bend in the waveguide near the horn and by modifying the feed-horn window in October 1984.

C. ANTENNA MOUNT

The antenna mount is now operating after several previously undiscovered problems were remedied. These included:

(1) A misalignment of the waveguide to the azimuth rotary joint which produced an asymmetrical stress on the rotary joint and accelerated wear in the rotary joint bearings.

(2) Adjustments to the servo amplifiers that failed to take into account moment-of-inertia differences between the antenna and the concrete block used to emulate the antenna during testing at Lincoln.

(3) Deficiencies in the oil-pump monitoring system.

The mount is meeting the 30°/s maximum-velocity objective, but the azimuth accelerations are less than the $15°/s^2$ objective when under computer control. The discrepancy here appears to arise from differences in servo operation under computer as opposed to manual control, and will be resolved when the mount again becomes operational in October 1984.

The lightning strike damaged the power amplifiers, the synchro-to-digital converter (which provides antenna pointing angle), and the digital comparator. Scientific Atlanta will repair the power amplifiers and synchro-to-digital converter before turning to the digital comparator. This will permit us to verify mount operation in a manual mode as quickly as possible.

D. TRANSMITTER/RECEIVER

The ASR-8 transmitter and receiver appear to be operating satisfactorily. The spectral stability was rechecked in August when the signal processor and DAA processors had been fully integrated, and it was again satisfactory. The transmitter and receiver were only slightly damaged by the lightning strike. However, it will be necessary to recheck the system stability when operating on local diesel power.

E. SIGNAL PROCESSOR

The signal processor was kept at Lincoln until late June to debug and test the autocorrelator section of the signal processor with the radar simulator. For this testing, the clutter filter was bypassed, so that an unfiltered data stream was being processed. All three sections of the autocorrelator appear to be functioning properly. The clutter filter sections are in the process of being checked out.

The integration testing in Olive Branch was delayed by the need to identify and repair damage which occurred during shipping and then by the lightning strike. We anticipate completing

the basic signal-processor checkout by mid-November 1984. We will then turn to checking out some of the less-critical features such as second-trip processing and time-series recorder output buffering.

F. DATA ACQUISITION AND ANALYSIS (DAA) PROCESSOR

All the remaining processing element boards for the DAA (see Figure II-4) were received from the wirewrap vendor in July. Debugging and checkout of a second DAA processing element (PE) were completed in August. This PE was integrated with a multiple-port-memory (MPM) and monitor board to form a software development system identical to the test-bed system now in Memphis. The availability of this second system at Lincoln is a key element in the timely development of DAA software, as it allows the debugging and integration of program modules to proceed without interfering with test-bed operations. When new DAA software is installed in the test-bed, it should require a minimum amount of debug time to make it operational.

Checkout of the remaining DAA processing element boards was significantly slowed by wirewrap errors. In September we started using a microprocessor-based test fixture to check out the basic functions of the PE boards, with final testing to be done in the DAA system chassis. This checkout is a slow process, and there are many boards to check (5 in hand, 7 more to be constructed soon). An RFI for additional test engineers has been written, and should be sent out shortly.

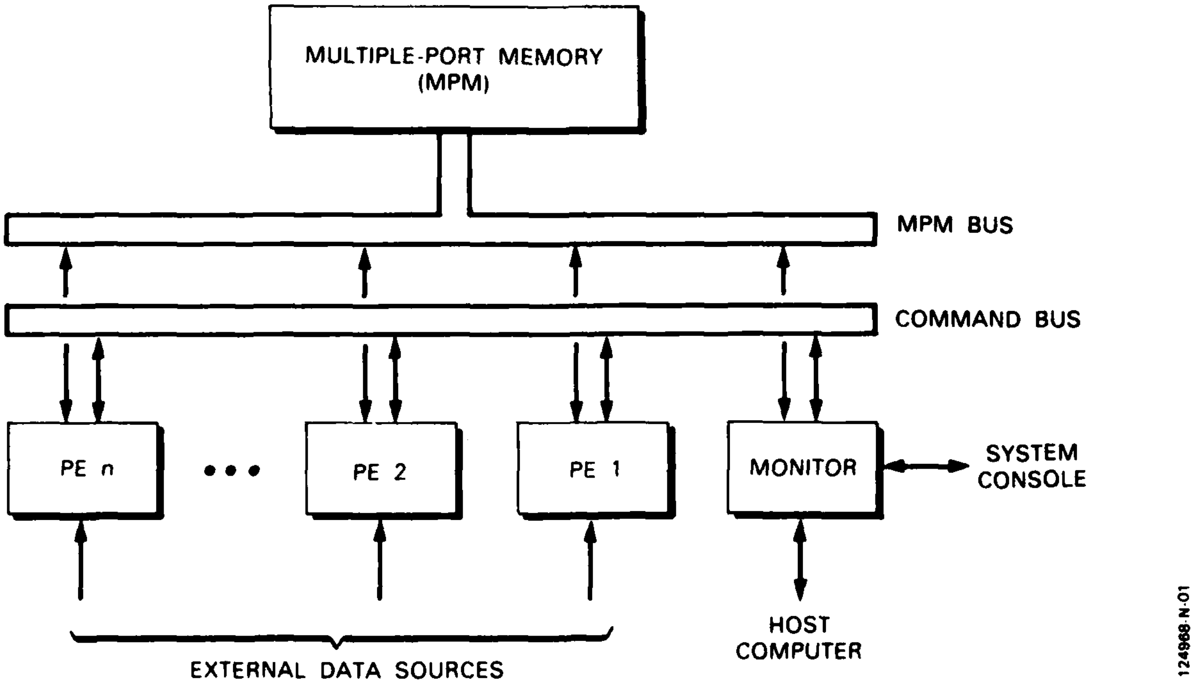

Figure II-4. DAA processor architecture.

The testing issue is a very significant one, since the desired DAA capabilities for the summer 1985 test-bed experiment (Memphis) will require a total of ten PEs to be working.

The DAA software development was slowed by the need to bring the hardware on-line. Two DAA diagnostic programs were developed to aid in the analysis of I/Q data generated by the signal procesor A/D converter. These programs produce histograms of I/Q inputs and display them on an HP vector graphics display. A package was completed of DAA arithmetic subroutines and MACROs, including general-purpose routines used for normalization, multiplication, division, and calculating square roots. A significant amount of time was spent expanding the DAA MICAS (microcode assembler) instruction set to facilitate assembly of the arithmetic package.

The major focus for DAA software in the immediate future will be the accomplishment of autocorrelation lags to moment conversion and resampling of the data from the (r,θ) measurement grid to a Cartesian (x,y) grid. All "lags-to-factors" (ratios and combinations of moments) arithmetic and data-formatting routines have been debugged.

File-handling and data-transfer routines have been written but not debugged. The "factors"-to-moments routines will be developed in the next quarter.

G. RADAR AND ANTENNA CONTROLLER

The Perkin-Elmer (P.E.) 3210 minicomputer used for radar and antenna control was slow in coming up at Olive Branch due to difficulties in arranging for installation service. It is now operating satisfactorily. An additional 2 MB of memory was added in July to facilitate real-time operation.

Several programs became operational:

(1) A program for use by the Lincoln Mechanical Engineering Division to test and calibrate the pedestal and controller. This program has been modified several times to accommodate their requirements and to test command sequences for possible use in real time.

(2) A pedestal control task to record status, operator requests, and pedestal commands as an aid in debugging the code or for gathering statistics to verify expected operation.

(3) A test program to allow operator control of the pedestal control task for testing purposes. This will allow the pedestal to be exercised as it will be exercised in real time, and also allow real-time features to be tested before the radar-control program is ready.

(4) A program to point the antenna at the sun is being adapted from the program previously used at the FAATC in 1980. This will allow us to determine correct antenna pointing and check system calibration.

(5) The inter-machine communications and central control tasks for the radar controller computer were completed, and basic testing begun.

We successfully executed some volume scans and sector scans in August, before the lightning strike occurred. The RHI program will be tested when the mount is repaired.

H. MAIN MINICOMPUTER

The P.E.-3252 minicomputer was particularly slow in coming up in Olive Branch due to the previously mentioned delays in initial turn-on as well as a rash of problems involving the replacement of boards which were not stocked by the Memphis P.E. field service office. We are discussing means of reducing such problems with Perkin-Elmer. An additional 4 MB of semiconductor memory was installed in late July.

In June, the P.E.-3250 portion of the real-time system performed an end-to-end test accepting simulated DAA inputs and generating the basic weather outputs of reflectivity, velocity, and turbulence. This was accomplished before the dismantling of the test-bed for shipment to Olive Branch, Mississippi.

Specific milestones included: the completion of the initial aircraft display capability with both interactive and stored commands for definition of aircraft in the real-time system, a rewrite of the log server task along with the interface routines that define three classes of messages which can be displayed on two different logging devices; continued testing and debugging of those parts of the real-time system which are critical to operation and can be tested in the current P.E.-3240 configuration; and display of base products on the color monitors. Some evaluation was done to arrive at a trial set of colors and thresholds for initial operation. An initial zooming capability was added to the display software.

After the test-bed was shut down on 10 June to prepare for shipment, software development continued using the "analysis" P.E.-3242 at Lincoln. Several days of effort went into recasting the existing test-bed software so that a subset of it could be run on the 3242 computer.* In that context, several additions were made to the real-time test-bed software, and the changes were tested. Most notably, the processing of radar data was reorganized to allow display processing of a selected tilt while succeeding tilts are being recorded in situations where there is a high volume of data.

The July effort focused on bringing the real-time software for the P.E.-3250 closer to a base-level data acquisition and display capability. Continued testing revealed several flaws which were repaired. In addition, new system control commands and data items were added to enable or disable usage of the trackball by the operator.

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* By the end of July, the 3242 computer memory was increased to 8 MB so that the full 3252 real-time program could be run at Lincoln.

In August, we added new commands which will enhance user interpretation of real-time meteorological display data by providing an overlay capability for state boundaries, grids, waypoints, etc., trackball service, and a method for displaying on-line documentation. We determined that the prototype trackball became inoperative during shipment to the test-bed; it was returned to the Laboratory for repair, thus postponing trackball efforts until a working device was available. Overlay capabilities were completed in September.

The final integration testing planned for September had to be deferred until the lightning damage was repaired. However, the test-bed real-time program was enhanced to estimate turbulence ($\epsilon^{1/3}$), as well as reflectivity and mean velocity. We are still not estimating S/N ratio in real time due to processing time constraints. Further improvements were made in the speed of the resampling algorithm. To alleviate some of the processing time constraints, we initiated the purchase of an auxiliary processing unit (APU) for the test-bed's central minicomputer. The APU should increase the computing power of the system by about 50 percent.

I. TEST-BED ENHANCEMENTS

As a result of informal discussions with the FAA regarding possible development of a C-band test-bed-like weather radar for use at Denver in 1985 or 1986, several studies of enhancements to the test-bed capability and data base were initiated.

A software simulator for the test-bed signal-processing system has been started which will serve two major purposes. First, it will be a source of test data, so that given signals may be run through the actual circuitry and compared with the simulated results. Second, the simulator will allow the detailed effects of the AGC scaling and finite precision arithmetic in the filter to be determined. This simulator represents a significant software effort, and will take some time to complete.

Reliable automatic de-aliasing of Doppler velocities is essential for the terminal Doppler weather radar (TDR). An attractive approach to this problem is to use staggered PRF pulse sequences. However, it is very difficult to obtain good clutter filter performance with such sequences. In mid-June, a study was initiated to develop techniques for clutter suppression in sequences in which the inter-pulse spacings alternate from pulse to pulse. The initial focus was on the development of staggered PRF clutter filter design techniques and simulation packages for the evaluation of weather parameter estimate degradation caused by the filters.

An autocorrelation-based synthesis procedure was developed which, when initialized with typical distributed clutter and a generalized weather spectrum (cost function), provides over 40 dB of clutter rejection over the range of NEXRAD clutter widths — with three filter coefficients. It has become apparent, however, that the passband and transition region performances of high-pass filters which operate upon unequally spaced data are almost wholly determined by the choices of stagger ratio and filter length.

The PRF stagger ratios which provide the steepest transition regions and smoothest pass-bands, and hence have the best reflectivity estimate performance, have proven to be unfavorable to velocity de-aliasing. Velocity de-aliasing is most reliable for low stagger ratios (e.g., 2:3), which imply a small number of folds at either rate, while the stagger ratios mentioned above are closer to 5:7. Phase contamination of the filtered pulse sequences, which affects velocity estimates, is the primary remaining issue to be resolved.

A new composite clutter filter architecture, incorporating filters which operate on both equispaced and unequally spaced pulse sequences, has been developed; preliminary evaluations indicate that it will be able to better satisfy the competing requirements for estimating spectral width, reflectivity, and velocity, while providing sufficient clutter rejection.

In August, we were requested by the FAA to assess the feasibility of constructing a second Doppler weather radar which could be used for wind-shear detection near Stapleton Airport, Colorado in 1985 or 1986. A preliminary assessment concluded that the antenna mount would be the pacing element in development of such a radar.

Delivery times from the NEXRAD subcontractors were found to be incompatible with a 1985 construction completion date, and possibly marginal for 1986. We made a trip in August to an antenna/mount museum in Florida, but no satisfactory mounts were found. There may be some suitable military mounts available and we will assess this possibility in the next quarter.

III. MEMPHIS SITE PLANNING AND SUPPORTING SENSORS

A. SITE SELECTION AND PREPARATION

1. Lincoln Radar Site

The roads, buildings, and pads for the site were completed in June. However, it was clear after several weeks of on-site experience that covered walkways between the buildings would be needed as well as continued road maintenance. These were installed in August.

The basic utilities are operational, although phone lines between the site and the Memphis ARTCC continue to be a problem due to the long delays by AT&T in installing a dedicated line. Currently, we are using an FAA microwave link to Byhalia, Mississippi with local phone company lines to the site as an interim solution.

As mentioned earlier, additional lightning protection systems will be installed at the site in October and November 1984.

Additional construction is occurring in the industrial park near the radar site. A trip will be made to the industrial park headquarters in early August to determine the impact of these additional structures on the site radar horizon. We will carry out analytical and experimental measurements of the blockage and scattering by new obstacles which have elevation angles above the previous horizon to ascertain whether we will need to increase the antenna phase center height.

2. University of North Dakota (UND) Radar Site

The site for the UND C-band weather radar became operational with the erection of the Lincoln TMF tower and installation of the UND radar on the tower. Figure III-1 shows the

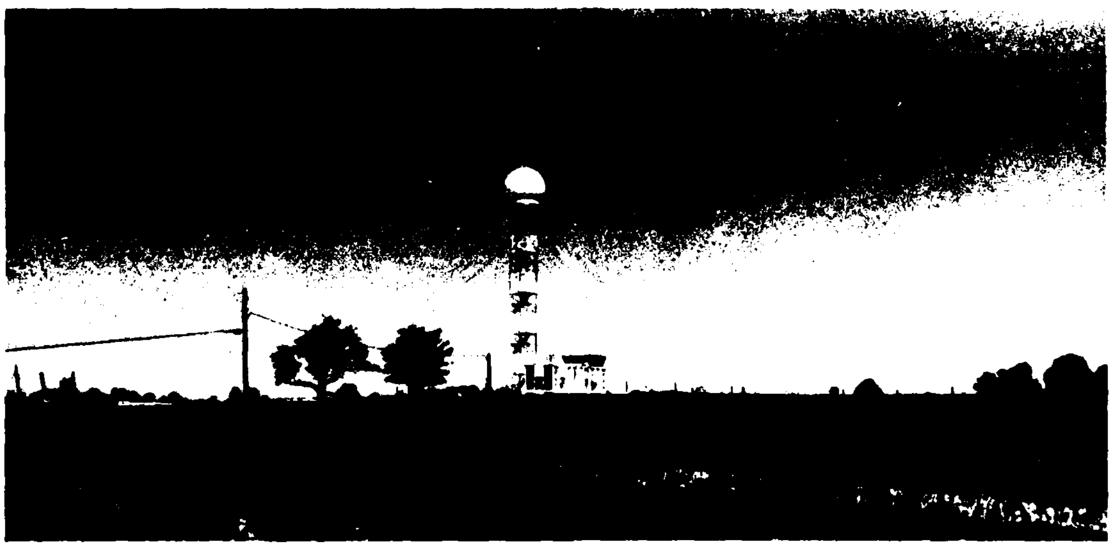

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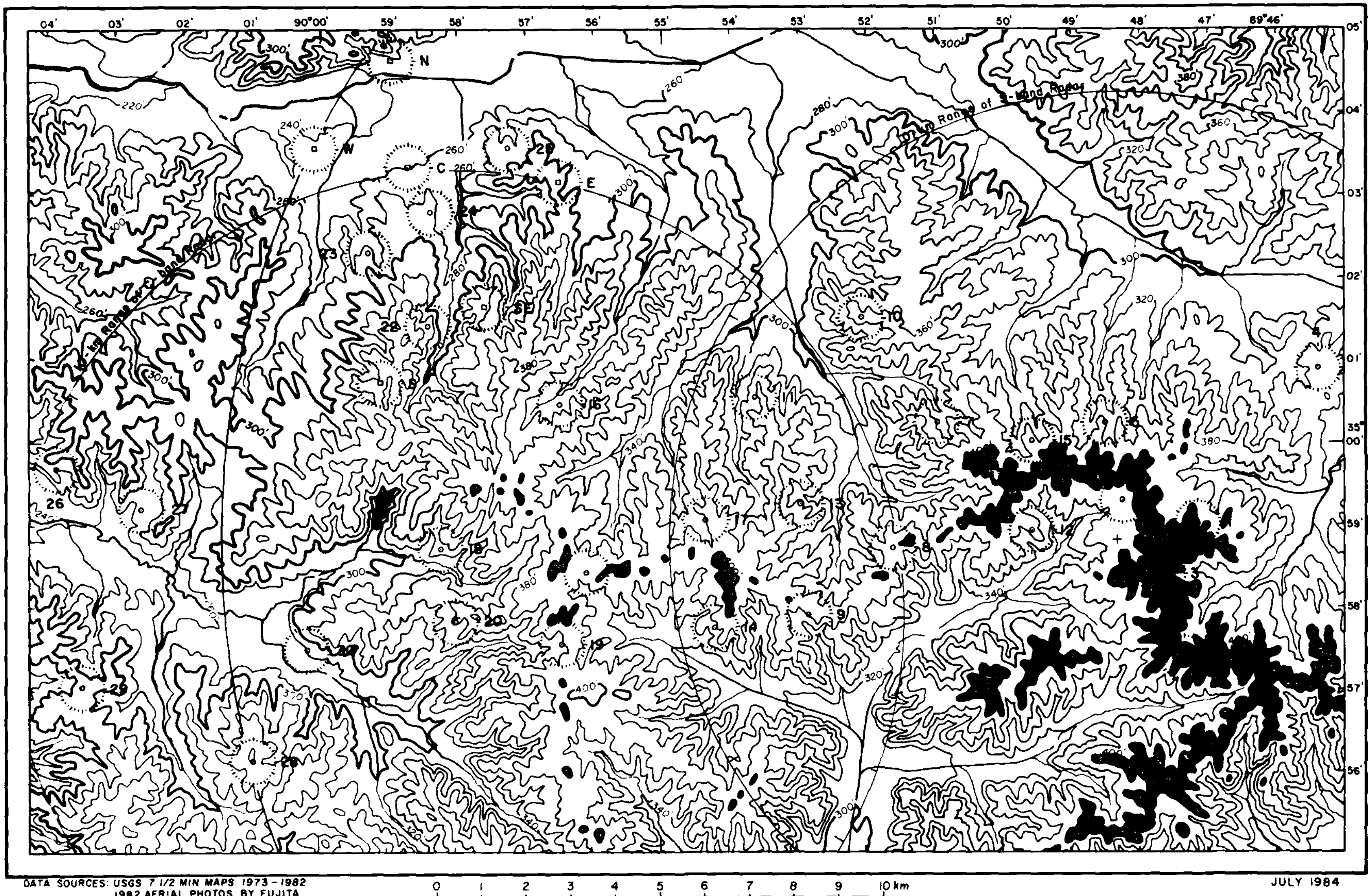
Figure III-1. University of North Dakota Doppler weather radar at Hernando, Mississippi site.

FAA / LINCOLN LAB WIND-SHEAR MESONET AT MEMPHIS, TENNESSEE



DATA SOURCES: USGS 7 1/2 MIN MAPS 1973 - 1982
1982 AERIAL PHOTOS BY FUJITA
MAPPING & CARTOGRAPHY: T THEODORE FUJITA

JULY 1984

UND radar atop the tower on 4 July. The electric fence around the tower has been repaired and marked with flags to prevent horse owners from inadvertently knocking it down.

When the UND radar was removed on 15 September, the TMF tower was taken down and stored at Burkeen Industries in Olive Branch. The tower anchor cables were left in place and the land lease was renewed for FY85 so that measurements can commence quickly when UND is returned in spring 1985.

3. Mesonet Sites

Five additional sites have been selected, and four landowner agreements have been signed. We are having difficulties reaching an agreement with the site #27 landowners due to various issues raised by their lawyer. If these cannot be resolved by early October 1984, we will find another site.

Professor T. Fujita traveled to Memphis and took panoramic photos of the sites in July. He has had color maps printed showing the location of all 30 of the mesonet stations along with the LLWSAS sites, the radar sites, and the underlying topography (Figure III-2).

A schedule was distributed for mesonet action items that will take place between now and the early part of next spring. We decided that, even if we intend to leave the Memphis area earlier, the landowner contracts for rental of the mesonet sites should be renewed for an entire year (through 30 September 1985). New landowner contracts have been signed, and checks are being issued to the landowners.

B. SUPPORTING SENSORS

1. Mesonet Operations

The mesonet stations continued to transmit data reliably. A Data Collection Platform (DCP) whose clock appeared to jump after about two weeks of operation was returned to Synergetics. They did find a loose screw, but no obvious problems. A problem was found with another DCP that quit transmitting when the interior temperature reached approximately 95°F. This was sent to Synergetics when the other DCP was returned.

Early in September we learned that the fall eclipsing of the GOES satellite is taking place from 30 August to 15 October 1984. This will affect the status of the GOES satellite, which will thereby affect our mesonet data. Some of the mesonet data between 0530Z and 0730Z may be lost during this time period.

2. LLWSAS Recording System

The LLWSAS recording system at Memphis International Airport continues to work satisfactorily. We have not experienced any loss of data since installing a backup power module.

3. University of North Dakota (UND) Radar Operations

The UND C-band Doppler weather radar commenced operations in early July. However, the first two weeks were spent in shaking down various system problems including recording formats, azimuth-angle readout, etc. which involved code changes by Enterprise Corp. The antenna control program currently permits only 360° volume scans at equally spaced elevation angles in automatic mode, with RHI scans being available under manual control.

The other significant limitation in UND operation is the excessive computation time by the Sigmet processor. Measurements at the site suggest that 100 ms is required to process 32 radar pulses for 226 range gates. The radar is normally operated at its peak PRF of approximately 1000 Hz to minimize velocity folding. Thus, the slow computation time results in:

(a) The processor ignoring data from two-thirds of the potential pulse integration, and

(b) A maximum scan rate of 2.7 rpm if the angle estimates are to be spaced 1 beamwidth (1.5°) apart.

UND is investigating means of alleviating this problem in 1985.

The instability spectra measured on fixed targets at the UND site were similar to those measured in late 1983 and suggest a maximum clutter cancellation of approximately 25 dB due to the radar instability.

UND made measurements on approximately nine storms in the 25 July to 14 September time period, with the most significant weather occurring on 11 August. The UND radar shut down on 15 September to be returned to North Dakota. The data tapes from the UND measurements will be sent to Lincoln in the next quarter.

4. Aircraft Support

The lightning damage to the Lincoln test-bed precluded any aircraft measurements, since the UND radar has no capability for real-time aircraft position display. Therefore, we canceled the planned flights by the UND and FAATC aircraft for the remainder of 1984.

5. Additional Weather Data

The Harris Laser fax recorder for satellite imagery and the RRWDS display system are both operational. The RRWDS currently is used to furnish real-time warning of convective cells so that the site can be shut down to avoid lightning damage. Unfortunately, the satellite imagery recorder must also be shut down at such times as well, so we do not have a complete image sequence for all the storms measured by UND.

6. Additional Clutter Data

There is an urgent need for representative TDR clutter data for use in determining TDR siting strategies. Measurements at a variety of on- and off-airport sites are required. However, it

now appears that the test-bed radar will typically visit only a single site per year. To significantly increase the available clutter data base, arrangements were made with the Lincoln Air Vehicle Survivability Evaluation program to use their Phase 0 X-band clutter measurement system for measurements of opportunity at Dallas-Ft. Worth (DFW) airport, Eglin Air Force Base/Fort Walton Beach, Florida, Memphis airport, and the Olive Branch, Mississippi test site.

Figure III-3 shows this system at Lincoln Laboratory. Table III-1 summarizes the radar operating parameters, while Figure III-4 shows a schematic of the radar system processing for clutter data. Measurements were carried out at DFW airport on 28 August 1984 at the location shown in Figure III-5 at antenna heights of 20 and 50 ft. This site was viewed as appropriate for an "on-airport" TDR since it lies near the intersection of the three currently active main runways at DFW (runway BR-316 is under construction).*

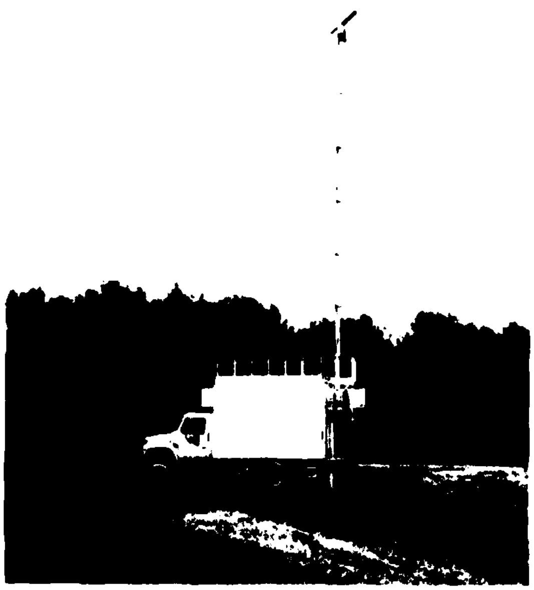


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Figure III-3. AVSE program phase-zero clutter measurement system.

* It should be noted that when runway 13R/31L becomes active, it will be virtually impossible to find a single site at DFW which can measure "along runway" shear for all the major runways.

TABLE III-1

Phase-Zero Radar Parameters

Transmitter

Frequency	9375 ± 30 MHz
Power	50 kW peak; 45 W average
Operating Modes	

Maximum Range (nmi)	3	12	64
Pulse width (μs)	0.06	0.5	1
PRF (pps)	3600	1800	900

Receiver

IF Attenuation (dB)	0 to 50 in 1-dB steps
Noise Figure	10 dB

Antenna

Type	9-ft, end-fed, slotted array
Polarization	Horizontal
Rotation	17.6 rpm
Beamwidth	0.9° azimuth; 23° elevation
Gain	30 dB
Sidelobes	30 dB below peak

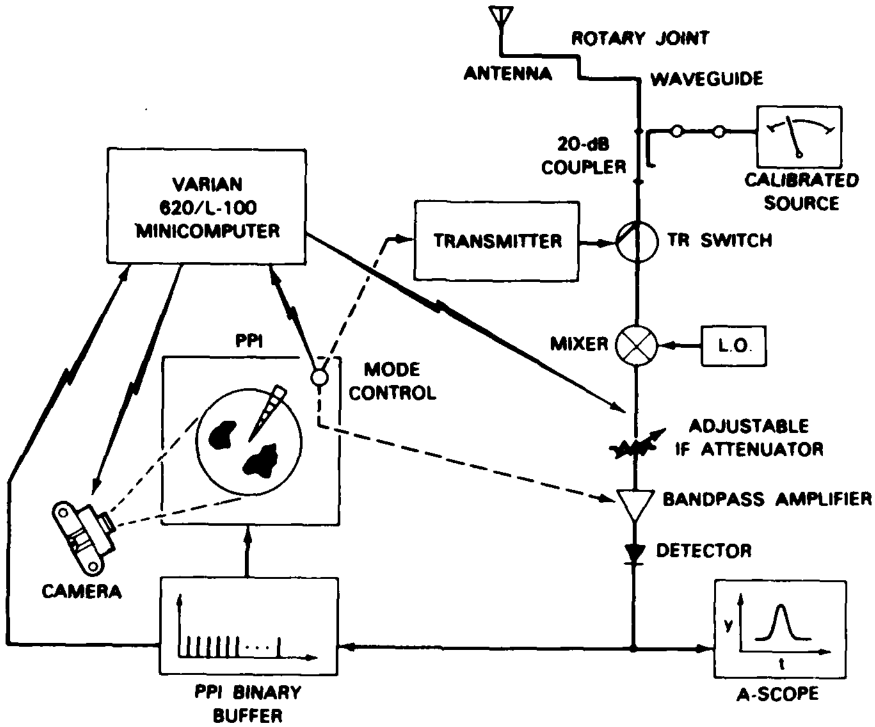

Figure III-4. Phase-zero radar schematic.

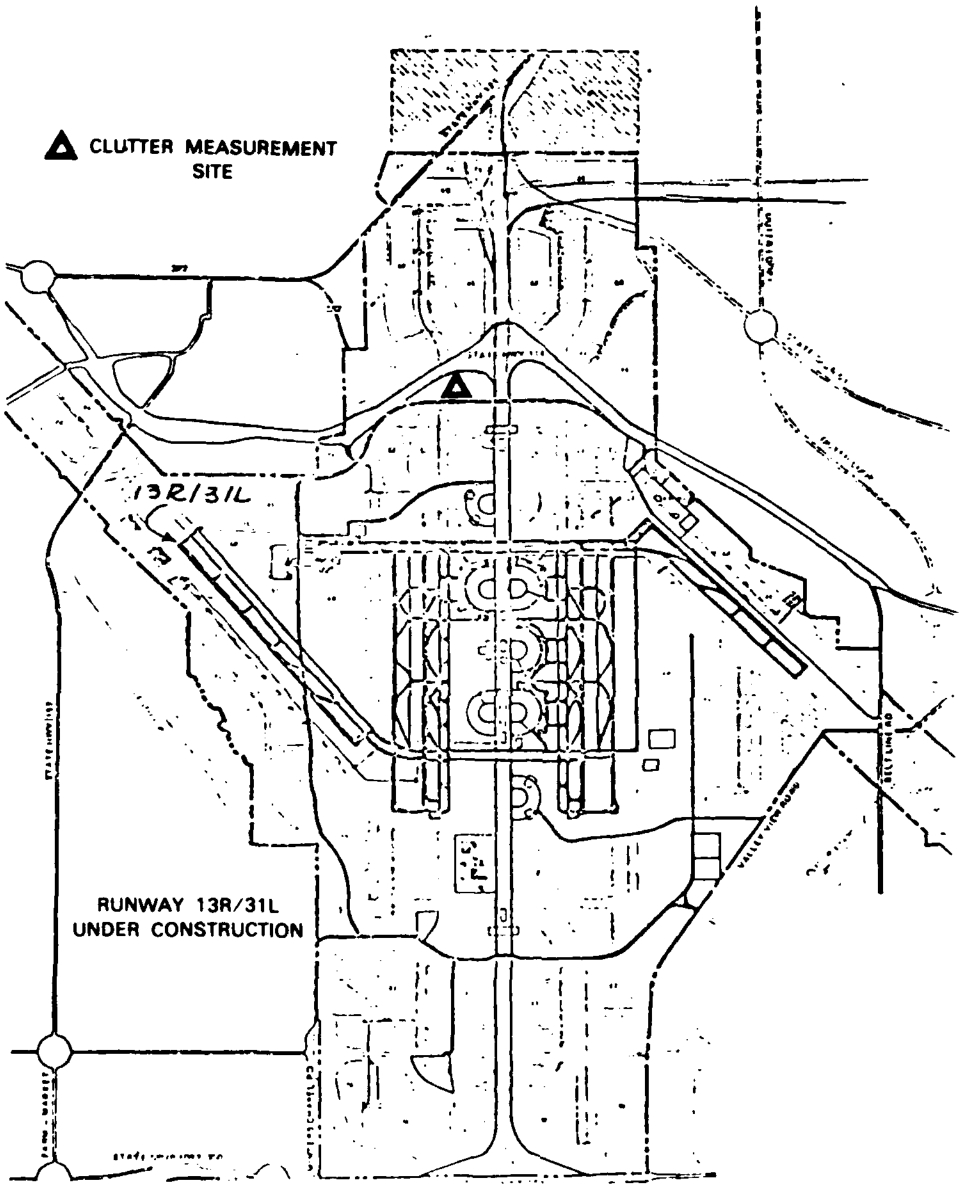

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Figure III-5. Dallas-Ft. Worth airport.

IV. EXPERIMENTAL DATA REDUCTION AND ALGORITHM DEVELOPMENT

An additional used Perkin-Elmer (P.E.) 3242 computer was delivered in late August, but has not yet become operational due to delays in deliveries of the system disks and in equipping the room in Annex V for the computer. Some 6 MB of additional semiconductor memory was purchased for this and the other P.E.-3242 data analysis computer to speed up the systems and facilitate development of real-time software for the test-bed.

The "dither" feature on the Dunn camera was made operational in September. This feature smears the image being photographed, along the vertical axis, to fill in the gaps between the raster scan lines. The result is a solid image (as opposed to an image consisting of a set of horizontal lines), and the brightness is much improved. Additional improvements to the Dunn system are planned, so that the camera may be conveniently used to create the high-quality photographs it was intended to provide.

In the next quarter, we plan to connect the two P.E.-3242 computers via a fiber-optic link so that the P.E. Pennet software can be used to exchange data between the two systems. Also, the computer display terminals, line printer, and one of the tape drives will be moved to the Annex V computer to reduce the need for programmers to continually walk back and forth between the buildings.

The number of people involved in data analysis continues to grow. An additional full-time programmer and two summer employees commenced work in June, as did an analyst. However, we are still understaffed in this area. Two additional contract programmers were hired in September to work on low-altitude wind-shear (LAWS) data analysis and algorithm development and will commence work in October 1984. We are also hiring a daytime computer operator to oversee system maintenance and to run batch jobs.

To facilitate the education of these new personnel, an introductory course in Doppler weather radar as applied to hazardous weather detection was presented to 30 participants from within the project as well as from the FAA, Martin Marietta, the Jet Propulsion Laboratory, FAA Technical Center, and MITRE Corporation. Copies of the course notes and videotapes of the course lectures were sent to each of the external organizations so that the material could be presented to people who did not attend the course at Lincoln.

The software emphasis continued to be on developing the software utility packages for turbulence and LAWS analyses. The radar data analysis package matured considerably during the quarter, while the mesonet data analysis package development commenced in earnest.

The increased software development activity has made it necessary to formalize procedures for handling the common-use programs and documentation. A "software documentation manager" has been designated and a "permanent program" account has been designated for the mature "common-use" programs.

Software reviews are being conducted as warranted at the design stage and when the programs are written. We are also trying to create more closely spaced milestones in the software design phase to aid the monitoring of software progress and to improve our ability to estimate the time required to develop programs. A software coordinator/consultant has been designated to participate in all software reviews and to aid in milestone monitoring.

Progress in each of the major areas is described below.

A. RADAR DATA REDUCTION

The programs to translate various radar tapes into a common format for use by the Lincoln analysis package were largely completed. Conversion packages now exist for:

(1) NSSL "universal" format and JDOP format,
(2) NCAR (JAWS project) "universal" format,
(3) MIT tapes from the summer 1983 experiments, and
(4) Memphis test-bed tapes.

These translators have proven time consuming to develop due to problems in resolving various radar features (including calibration factors) and in identifying when volume scans and tilts start or stop.* We plan to have the University of North Dakota write the conversion package from their summer 1984 tape format to "universal" format during the next quarter.

Three-dimensional wind fields derived from multiple Doppler analyses, as well as edited Doppler JAWS tapes, were provided to us by C. Kessinger of the JAWS project. These tapes are far easier to work with than the raw JAWS tapes, but contain sizable spatial gaps in many cases as a result of the editing process. It is essential that experimental tapes obtained in future experiments be obtained with clutter filtering, if LAWS algorithm development is to proceed in a timely manner.

During the next quarter, we anticipate commencing batch analyses of:

(1) The MIT data from summer 1983 for turbulence and LAWS events, and
(2) Clutter data from the Memphis site,

as well as continued studies of the JAWS and NSSL data sets.

B. MESONET DATA ANALYSIS

A major effort commenced to develop an analysis package for the mesonet and LLWSAS sensors since that is our major source of data on 1984 LAWS events in the Memphis area. There are four principal elements in this analysis:

(1) Translation of the data tapes to the Common Instrument Data Format (CIDF) and for subsequent analyses.

* For example, many research weather radars do not move smoothly from one elevation angle to another, thus making it difficult to ascertain when a new tilt commences.

(2) Identification of bad data, and conversion of good data to the desired quantities.

(3) Compensation for site obstruction effects in the wind data.

(4) Display of the cleaned-up data in a variety of representations.

Work was started on the first three elements during this quarter.

A calibration file for corrections to mesonet data was designed in August. Calibration information will be entered into a file in a specific format via the editor, and a program was written to read this file and translate it into a file of calibration information ordered according to platform, sensor, and date. Access routines have to be written which will allow programs to use this calibration information to correct the original mesonet data.

Access routines were written to allow the translator (which translates mesonet data into CIDF format) to access calibration information for each platform and sensor at a particular time. Since these calibration values will rarely change during one day, these routines were designed to store the calibration values for each platform and sensor and to access new values only when the old values are invalid. Other known data calibration procedures will include correcting the magnetic wind direction to true, and adding a known pressure proportional to station elevation to convert the measured pressure to mean sea level for analysis.

The relative humidity (RH) values from the Memphis mesonet have been reading too high. Five cases were found where heavy rains affected the mesonet. From these cases, maximum values of RH were found for each of the operating 25 sensors. These values will help in determining a correction factor for the RH.

We are analyzing the wind speed as a function of wind direction and visible obstruction height for each station. The derived correction factors (every degree in azimuth for each station) will be applied as part of the calibration procedure.

Considerable effort was spent developing a program that will smooth the Memphis mesonet obstruction angles. The original obstruction angles were calculated from panoramic photographs at each of the mesonet stations by Ted Fujita. These smoothed angles will be used in determining the corrections (as a function of azimuth) for the winds at each site.

C. LOW-ALTITUDE WIND-SHEAR (LAWS) ALGORITHM DEVELOPMENT

The principal activity in this area focused on developing the radar data analysis package described above. A summer study by a Harvard student, completed in September, assessed three techniques from the image processing field for edge enhancement in the presence of image noise:

(1) A mask matching technique suggested by M. Nagao and T. Natsuyama,*
(2) Median filtering, and
(3) Nearest-neighbor processing.

* In their book *A Structural Analysis of Complex Aerial Photographs* (Plenum Press, New York, 1980).

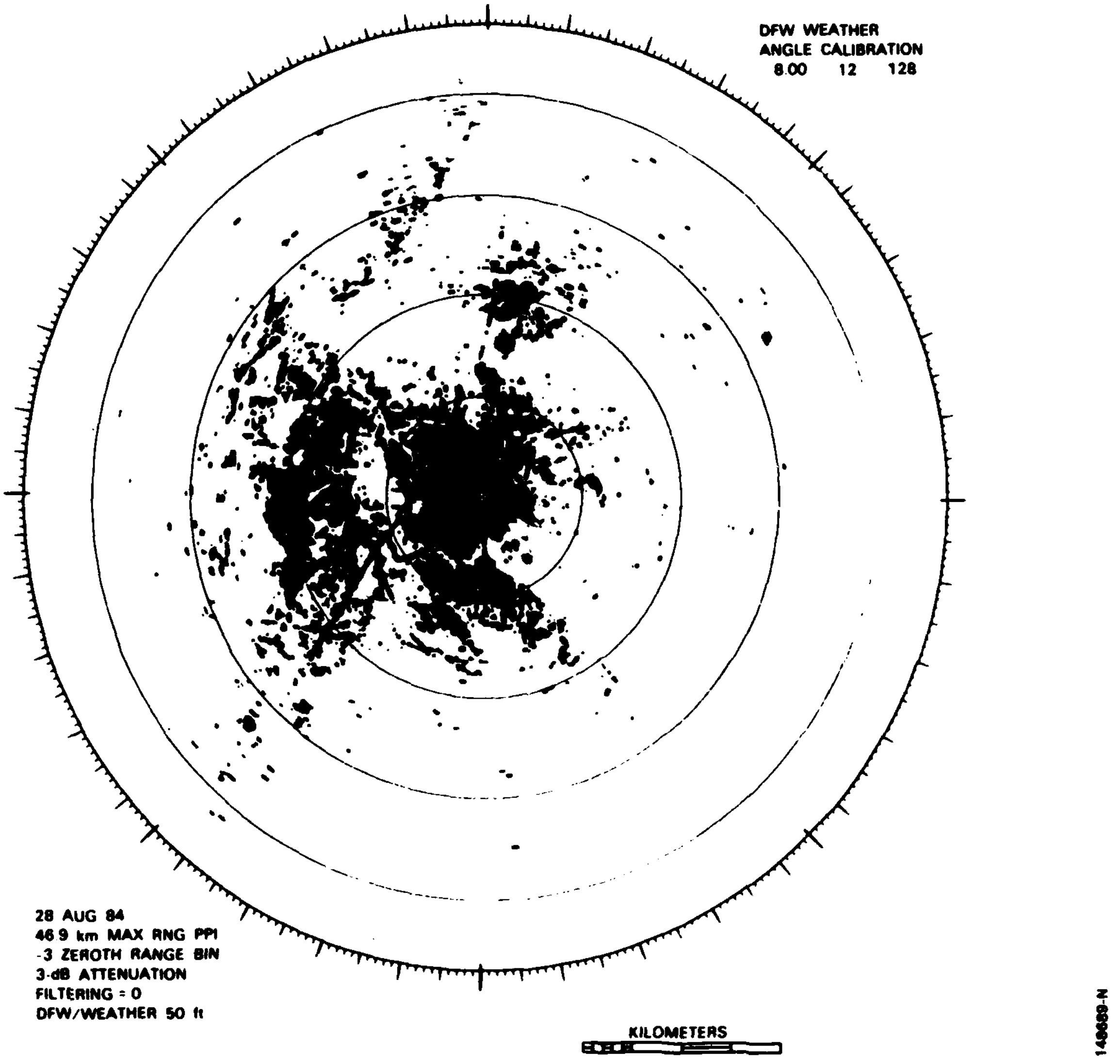

Figure IV-1. Clutter at DFW site with scattering cross section greater than -35 dB.

Tests were made using these techniques on three moment data fields and on gradient fields, and the results will be presented in a report to be published in the next quarter.

D. TURBULENCE ALGORITHM DEVELOPMENT

Turbulence algorithm performance in the context of the anticipated CWP product format will commence next quarter now that the various translator packages have been developed. Progress in this area was slowed down by departure of the staff member who had been principally involved in turbulence analyses.

E. CLUTTER ENVIRONMENT ASSESSMENT

Preliminary reduction of the DFW clutter measurement data was accomplished by the AVSE program staff. Figure IV-1 shows the regions where the clutter scattering cross section (σ_0) exceeds -35 dB. In the next quarter, we will develop software to:

(1) Convert the σ_0 levels to effective dBz levels, and

(2) Display the effective clutter levels taking into account suppression by clutter filters and/or clutter maps.

Additionally, we anticipate receiving data from Eglin AFB and the Memphis area sites.

V. ASSESSMENT OF UTILITY OF NEXRAD PRODUCTS FOR ATC USE

The Boston Area NEXRAD Demonstration (BAND) concluded operation at the end of June. A Lincoln-supplied Chromatics color display with NEXRAD Interim Operational Test Facility (IOTF) products was located in the CWSU area adjacent to the RRWDS displays to obtain feedback on the utility of NEXRAD products for aviation use. The demonstration highlighted the need for improved information on (squall) line storms. These storms are particularly challenging for the ATC system because:

(a) The large spatial extent makes weather avoidance costly in time and fuel.

(b) Tactical cell avoidance by large numbers of aircraft creates disorderly traffic flow.

(c) Central flow control keeps aircraft at their gates, thus impacting the entire ATC system.

The principal weather information needs in such cases are:

(a) To provide aircraft with guidance on best location for line penetration,

(b) To provide aircraft with prediction of gap locations,

(c) To provide identification of particularly hazardous regions, and

(d) To provide an assessment of near-term (1 to 3 h) development needed for central flow control.

The storm structure and hail information was useful in meeting these needs; however, deficiencies were noted in:

(a) *Tracking and Prediction*: The current centroid tracker performance is erratic in extended storms. Also, better prediction of "gaps" in the weather is needed and growth and decay, which are not currently considered, seem to be particularly important.

(b) *Three-Dimensional Storm Visualization*: The IOTF three-dimensional reflectivity cross-section product is not a NEXRAD product and its spatial scale is too small. A more useful vertical cross-section product requires algorithm development and testing. Also, time-lapse display may be required for growth/decay.

Unfortunately, the NEXRAD turbulence product and the layered reflectivity and echo tops map products were not available due to processor limitations.

We have followed up on the BAND results by circulating a questionnaire on alternative products for three-dimensional storm visualization to the Boston ARTCC CWSU meteorologists and to other researchers who are active in Doppler radar (e.g., NSSL, AFGL, PROFS). Figure V-1 shows the various alternatives. The arbitrary vertical cross section appears to be preferred. However, no current NEXRAD algorithm exists to produce this product.

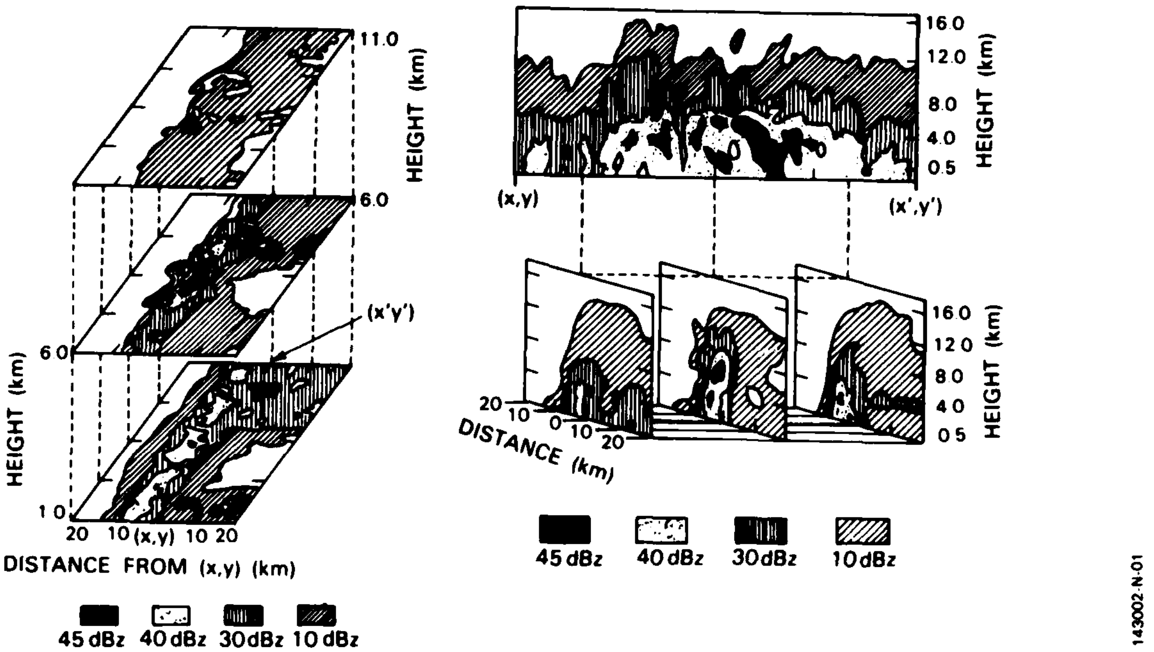

Figure V-1. Alternative three-dimensional representations for weather radar volume scan data.

Discussions with the FAA and NEXRAD JSPO in connection with the layering algorithm (see Section VI) re-emphasized the need for assessing the utility of the current layered products in a quasi-operational situation. It now appears that it will not be possible to carry out a real-time product investigation at the Longmont, Colorado ARTCC during the summer of 1985.

We are actively investigating methods for carrying out a study at the Memphis ARTCC in late summer or fall of 1985. Figure V-2 shows the recommended configurations using a high-resolution (e.g., nominally 1024 × 1024 pixels) color monitor such as is under consideration for the Sector Suite to display weather and/or aircraft reports. The high resolution is required so that aircraft symbols and alphanumerics will not obscure much of the weather, and to permit split-screen display of several images simultaneously. Compression techniques will permit a greater variety of products to be available for investigation, while a local computer will enable the user to rapidly display (e.g., 1 s to change screen) a variety of products.

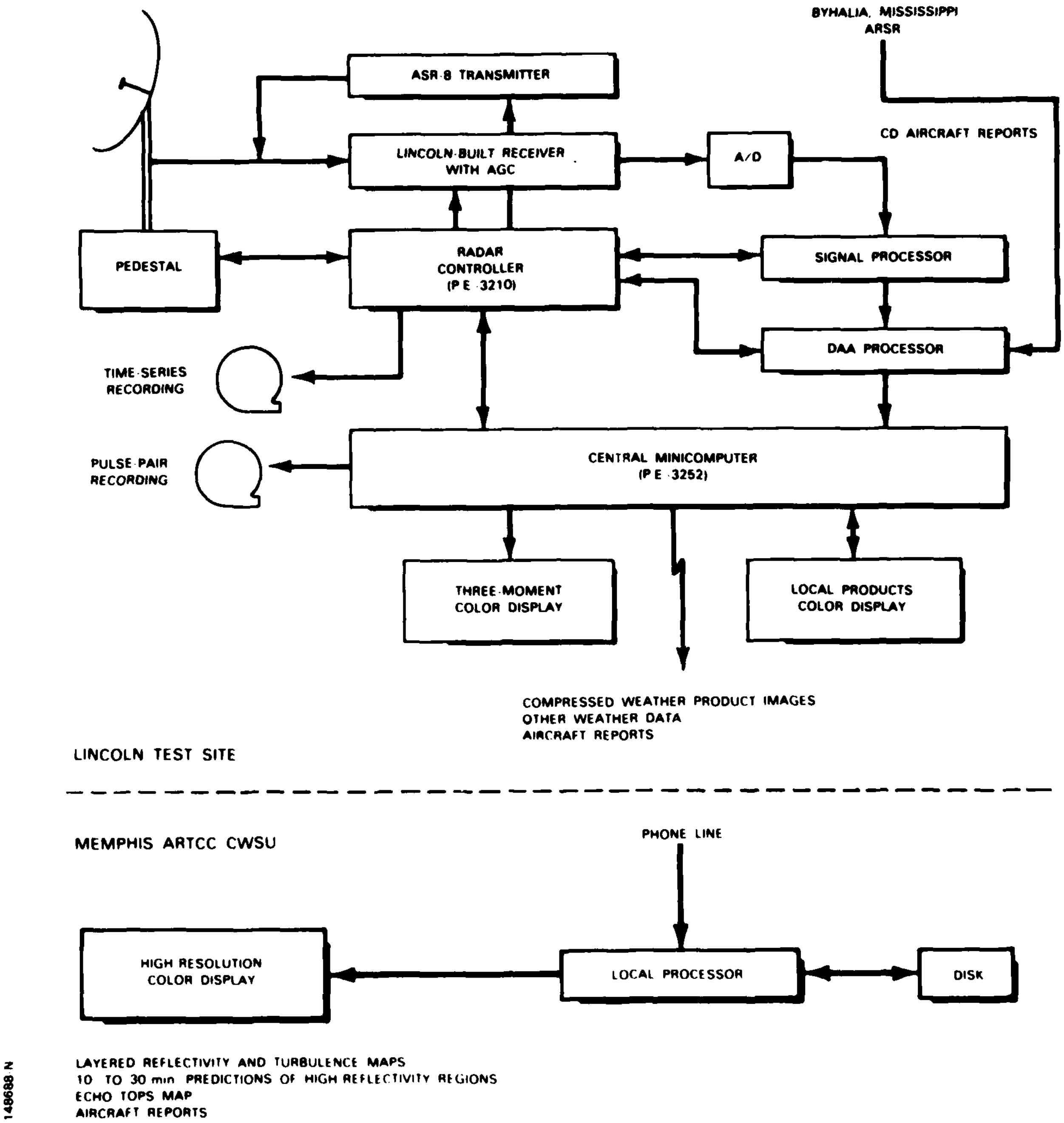

Figure V-2. Display configuration for NEXRAD/CWP product demonstrations at Memphis ARTCC.

VI. SPECIFICATION OF NEXRAD PRODUCTS FOR THE CENTER WEATHER PROCESSOR (CWP)

A. LAYERING ALGORITHM DEVELOPMENT

Much time was spent this month developing a functional specification for the NEXRAD Layer Composite algorithm, and examining various alternative implementations. This work was prompted by complaints (to the JSPO) from the NEXRAD contractors, stating that the layering algorithm would not fit in their validation phase processors. Mark Merritt sent a basic specification to the JSPO, and has largely finished his implementation study report. This study indicates that the layer composite process can be performed in as little as 5 s per tilt, with a 9-tilt volume scan requiring less than 25 s total CPU time. These figures include certain approximations, but are within the specified accuracy limits imposed by the functional specification.

In connection with the layering algorithm efficiency issue, Mark Merritt met with Frank Amodeo of MITRE, to discuss alternative implementations. Mr. Amodeo has been tasked by the FAA with evaluating the relative complexity of the layered algorithm with the CAPPI products originally specified in the NEXRAD products list. Mr. Merritt also responded to questions posed by Brad Sutker of SASC, arising from the PROFS' validation of the NEXRAD Layer Composite algorithm description.

B. TRACKING AND PREDICTION

A Project Report* on *storm tracking and prediction* was issued. Sizing and timing details of the correlation algorithm were given to Brad Sutker of SASC for incorporation in their report on that algorithm.

The NEXRAD BAND review from the winter period indicates that the current NEXRAD centroid tracker performs erratically on extended storms. Since Nashua CWSU meteorologists indicate that ATC has a greater need for accurate tracking of extended storms, the current NEXRAD tracker must be examined closely in the context of aviation needs.

We have had several discussions with NEXRAD IOTF personnel regarding the merits of various approaches to storm tracking. D. Zittel of the IOTF has also suggested use of a correlation tracker for extended storm systems. The computational load for the current correlation tracker is significantly greater than that for the centroid tracker. Thus, in the next quarter we will consider methods of reducing the computational load.

* J.C. Brasunas, "A Comparison of Storm Tracking and Extrapolation Algorithms," Project Report ATC-124, Lincoln Laboratory, M.I.T. (31 July 1984), DTIC AD-A146638/2.

GLOSSARY

A/D	Analog-to-Digital
AGC	Automated Gain Control
AFGL	Air Force Geophysics Laboratory
APU	Auxiliary Processing Unit
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
AT&T	American Telephone and Telegraph
AVSE	Air Vehicle Survivability Evaluation
BAND	Boston Area NEXRAD Demonstration
CAPPI	Constant-Altitude Plan-Position Indicator
CIDF	Lincoln Laboratory Common Instrument Data Format
CPU	Central Processing Unit
CWP	Central Weather Processor
CWSU	Center Weather Service Unit
DAA	Data Acquisition and Analysis (Processor)
dBz	Unit of weather reflectivity
DCP	Data Collection Platform (implies transmitter to GOES satellite)
FAA	Federal Aviation Administration
FAATC	Federal Aviation Administration Technical Center
GFE	Government Furnished Equipment
GOES	Geostationary Operational Experimental Satellite
HP	Hewlett Packard
INS	Inertial Navigation System
IOTF	Interim Operational Test Facility
I/Q	In-Phase and Quadrature
JAWS	Joint Airport Weather Studies
JDOP	Joint Doppler Operational Program
JSPO	Joint System Program Office (for NEXRAD program)
LAWS	Low-Altitude Wind Shear
LLWSAS	Low-Level Wind-Shear Alert System
MB	Megabyte
MEM	Memphis International Airport
mesonet	Refers to a network of automatic weather stations with a close spacing, i.e., a "mesoscale" spacing. Lincoln's spacing might be called "microscale."

MICAS	Microcode Assembler
MIT	Massachusetts Institute of Technology
MPM	Multiple-Port Memory
NCAR	National Center for Atmospheric Research, Boulder, Colorado
NEXRAD	Next Generation Weather Radar
NIMROD	Northern Illinois Meteorological Research on Downbursts
NSSL	National Severe Storms Laboratory, Norman, Oklahoma
NWS	National Weather Service
OS/32	Perkin-Elmer operating system
P.E.	Perkin-Elmer
PE	Processing Element
PROFS	Prototype Regional Forecasting System
RFI	Request for Information
RHI	Radial Height Indicator
RRWDS	Radar Remote Weather Display System
SASC	Systems and Applied Sciences
S/N	Signal-to-Noise
TDR	Terminal Doppler Weather Radar
TMF	Transportable Measurement Facility
UND	University of North Dakota
UNIX	"Generic" operating system developed by Bell Laboratories
UPS	Uninterruptible Power Supply

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